THE OHIO JOURNAL OF SCIENCE

Vol. XXII APRIL, 1922 No. 6

THE SEXUAL NATURE OF VEGETATIVE OR DICHOTOMOUS TWINS OF ARISÆMA.*

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While studying sex reversal in Arisæma triphyllum (L.) Torr., the writer accidentally came across some interesting examples of dichotomous twins which have a bearing on the theory of sex determination. Twin flower clusters were reported several years ago by Pickett† who discovered about a dozen of such plants. He says the two flower clusters were surrounded by two leaves, and also makes the casual remark that the two clusters "are of the same sex on each plant and are entirely independent, arising from two separate initial groups."

The twin shoots and separated twins must not be confused with the normal lateral buds, which are produced each season from the corm. The main corm often becomes smaller, not only from accidents to the aerial shoots and poor growing seasons which reduce the available food supply but also from excessive or vigorous lateral bud production. In case of dichotomy of the growing bud which results in twins, one can find all gradations from simple inflorescences with slightly flattened spadices ending in two tips and with a double-pointed spathe to individuals which have two entirely distinct aerial shoots, identical in appearance and situated closely side by side. Such pairs of twin shoots become entirely separated after a year or more because of the further development of the two buds and the dying off of the back end of the corm. The twins can often be recognized as such for several years after com-

* Papers from the Department of Botany, The Ohio State University, No. 134.

† PICKETT, F. L. A Contribution to our Knowledge of Arisaema triphyllum. Mem. Torr. Bot. Club. 16:48. 1915.

plete separation, both because of their position in the ground, close together and with the buds pointing in the same direction, and because of the remarkable similarity of the vegetative characters and similarity in size. Occasionally there is a difference in size of the individuals, or in the length of the sterile tips of the spadices, or in the time of emergence from the ground. There is no reason why such differences should not be decided, since the original fission of the bud may be quite unequal. In the dichotomous branches of Vernonia baldwinii Torr. and V. altissima Nutt., for example, there is frequently a decided difference in the length and complexity of the two forks.* There might also be a difference in the more specific vegetative characters occasionally, for the same reason that the two sides of a symmetrically bilateral body may differ in the characters expressed as, for example, the differences in the details of venation of pairs of insect wings, differences in the lobings of the two halves of a leaf, differences in the colored spots of the heads of certain turtles which are usually symmetrical, and differences in the color of the eyes of dogs and men, where one occasionally finds individuals with one eye blue and the other brown. The same differences of expression must take place occasionally after separation of two bilateral halves of an egg or vegetative bud and it is, therefore, possible that identical twins may differ decidedly in very important characters.

Not only are the Arisæma twins, so far discovered, all remarkably alike in vegetative characters but they are of the same sex. Some are staminate pairs, some are carpellate, and some intermediate with both staminate and carpellate flowers on the spadix, just as is the case with normal individuals. But the most remarkable characteristic exhibited by the bisporangiate twins is that so far they have been identical or nearly identical in the distribution, position, and numbers of the staminate and carpellate flowers. Since the elaboration of the hypothesis of the Mendelian nature of sex, it has been supposed by some that the fact that identical or duplicate twins are apparently always of the same sex gave a very strong presumption in favor of the correctness of the chromosome-linked or Mendelian hypothesis. This is, however, not at all the case as will appear from the evidence given below, derived from a

* SCHAFFNER, JOHN H. Unusual Dichotomous Branching in Vernonia. Ohio Jour. Sci. 19:487-490. 1919.

study of a considerable number of twins of Arisæma, when it is remembered that sex in Arisæma has nothing to do primarily with chromosome shiftings and can be controlled and reversed almost completely by environmental means.

CHARACTERIZATION OF TYPICAL EXAMPLES.

1. A plant with twin leaves on a common petiole and twin spadices on a common peduncle. The two leaves each had three leaflets and had short petioles coming from the common petiole. The spathe had two points and surrounded the two spadices. Both spadices were pure carpellate and the sterile tips both had the upper two-fifths colored dark purple.

2. Twin shoots coming from the same corm. They were alike in size and general appearance. Both had the sterile tip purple. Both had identical sexual expression, being monecious with a zone of carpellate flowers below, covering about three-fifths of the spadix, and with a staminate zone above. Both inflorescences had purple-red anthers and greenish white stigmas.

3. A pair of large twins with separate corms but evidently just recently divided—probably the preceding summer. Both were very late in coming out of the ground; both had green spathes and green sterile tips; and both were pure carpellate with violet stigmas.

4. A pair of small twins with distinct corms but still close together. Both had green spathes and green sterile tips. Both were pure carpellate. One plant was 8 in. tall and the other 7½ in.

5. Large separated twins, both 12 in. tall to the tip of the spathe. The spathes of both were a uniform dark purple at the tip on the inside, and purple and greenish-white striped below. The sterile tips of both were dark purple above, purple spotted in the middle part, and green below. The sterile narrow stalks of the sterile tips were both purple spotted. Both were pure carpellate with pale violet stigmas.

6. A pair of twins just separated and situated close together. Both were 6½ in. tall to the top of the sterile tip; both had one larger and one smaller leaf; both had the spathes striped above, broad purple stripes alternating with narrow greenish-white stripes, and uniform greenish-white below. Both had the

sterile parts of the spadices purple mottled at the tip, with a solid band of purple just above the middle, and with a slight purple spotting below, extending from the purple band to the base of the sterile stalks. Both inflorescences were carpellate on the main part of the spadix with purple stigmas; and on the stalks of the sterile tips, a little way above the carpellate inflorescence, both had four purple-anthered staminate flowers! There was a slight difference between the two inflorescences in that one had a small, additional staminate flower in the top of the carpellate part, in addition to the four staminate flowers further up.

7. A pair of separated twins with green sterile tips but with their short stalks above the flower-bearing part slightly purple mottled. The spathes had green tips with purple stripes on their sheaths below. Both plants were robust. One was 12 in. tall to the top of the sterile spadix and the other was 11 in. Both were pure carpellate.

8. A pair of twins still united on the same corm. They were remarkably alike but one was slightly taller than the other, measuring 7½ in. while the other measured 7¼ in. Both had the sterile spadices or tips expanding decidedly toward the base. The tips were purple mottled while the bases were pure green. The spathes were greenish on the outside; but each had a broad band of purple on the inner side, one on the right side and the other on the left . The opposite sides of the spathes had a narrower purple mottled band, while the center of each was green slightly mottled with purple. The spathes, therefore, showed a decided right and left symmetry. The sheaths of the spathes were both folded clockwise, but this is a fluctuating character. Both inflorescences were pure staminate.

9. A pair of twins which developed in the writers experimental plots. The original plant was a pure carpellate individual brought in from the woods with others for experiments on sex reversal. This individual was treated for reversal to the male state by having its root system and leaves greatly reduced and being kept in a comparatively dry condition. The following year the growing bud showed that dichotomy had taken place, as the corm developed twin shoots. Both branches were pure staminate, being completely reversed in sex, along with a similar change in most of the other individuals in the plot that had been treated in the same way. The twins were of equal size and

character and developed at the same time. The plot containing the twins was then treated for reversal to the female state by an application of rich cow manure and abundant water supply during the entire spring and summer. The following spring (1921) the twins had both reversed their sex completely and were now pure carpellate again. Examination of the underground parts showed that the corms had separated, although with the dead part still united. The twins were now of unequal size and one was nearly a week earlier in coming out of the ground than the other.

Arisæma dracontium (L.) Schott.

Some observations and experiments were also made on the green-dragon. This species consists of normal monecious and staminate individuals with occasional abnormal intermediates.

10. A plant with dichotomous inflorescens. The spathe ended in two separate points, the free points being one inch long. The spadix was double but united except near the tips of the sterile part. The entire double spadix was staminate. One of the free sterile tips was five-eighths inch long and the other seven-eighths inch. There was also some difference in thickness.

11. A simple staminate plant was transplanted from the woods with others in 1920 and treated for continuation of the staminate condition. In 1921 it gave rise by dichotomy to identical staminate twins.

12. A pair of tall, robust twins that looked like monecious individuals, but both stalks were completely sterile, each having a small, abortive structure where the inflorescencs should have developed. They were still united on a single very large corm. This corm was transferred to the experimental plots in 1920 and treated for reversal to the staminate condition by reducing the root system and leaf surface decidedly. In the spring of 1921 both came up as pure staminate shoots. One came out of the ground a week earlier than the other.

CONCLUSIONS.

All of the twin Arisæmas described above showed a remarkable similarity in vegetative characters and were exactly alike in sexual expression. Since it has been established that the sexual state of Arisæma can be changed at will by proper

treatment,* it becomes evident that *identity of sex in duplicate twins can not be regarded as giving any conclusive evidence in support of the hypothesis that sex is determined by Mendelian factors.* As shown in the examples of twins described above in Numbers 9 and 12, the sex of twins has been completely reversed and the reversal was identical for each twin of a pair. The intermediate examples are even more striking than those with pure sexual expression. Cases like the one described under Number 6 must certainly be regarded as most remarkable in view of the fact that the sex of the individual is so easily changed. All these cases show that the nutritive balance or whatever it is that determines the sexual state must act with decided precision when individuals of like heredity develop under like conditions. Although so far the writer has no evidence that Arisæma twins placed in different environments would develop the opposite sexual states in any given season, yet, in view of the fact that any ordinary individual can be changed from season to season and that the pairs of twins have actually reversed their sex to the opposite state in agreement with a change in nutritive environment, it appears that such must be the case.

As shown by the examples listed above, certain pairs of dichotomous twins show fluctuation of a considerable degree, but so far this has been found mainly for size, folding of the spathe, emergence from the ground, and the like. The varietal characters, like coloring of the spadix and spathe, shape of the sterile spadix and length of its stalk, shape of leaflets, color of anthers and stigmas, etc., are remarkably alike in each pair and deviate only in minute detail.

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* SCHAFFNER, JOHN H. Control of the Sexual State in Arisaema triphyllum and Arisaema dracontium. Am. Jour. Bot. 9: 72–78. 1922.

EMERGENCE OF A MAYFLY FROM ITS NYMPHAL SKIN.*

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The emergence of a subimago mayfly from its nymphal skin observed by Superintendent George F. Miller and Captain Bickford, both of the Ohio State Fish Hatchery at Put-in-Bay, Ohio, and later described to me by them, impressed me as being of sufficient interest to warrant the addition of one more account to the number that have already been published regarding the subject of mayfly emergence.

The transformation occurred in a large, portable fish tank which had been standing for a number of weeks on the dock in front of the Hatchery building. This tank had been filled with water from the lake by means of a steam pump which had its intake lying very near the bottom and, presumably, the mayfly nymph had been drawn up with the water. Mr. Miller and Captain Bickford were standing at the side of the tank and were thus in an unusually fortunate position for observing the entire process of emergence. It occurred sometime during the month of June. The nymph swam upward from the bottom of the tank and when it reached a point about six inches beneath the surface of the water the nymphal skin split along its dorsal surface and the subimago began to push out. By the time it had reached the surface the subimago had freed itself entirely from the nymphal skin and was able to fly away immediately.

Neither of the men was familiar with the names of ephemerid species or the criteria for distinguishing them and therefore it is impossible to say to which one this individual belonged. The species which occur most commonly in the region of Put-in-Bay during the late spring and early summer are Hexagenia bilineata and Ephemera simulans.

Needham ('18) describes the emergence of *Hexagenia bilineata* as follows: "Transformation occurs at the surface

* Papers from the Lake Laboratory, Ohio State University, No. 74.

of the water and usually at night. The grown nymph swims up and floats. A rent appears in the skin of its back. The subimago suddenly emerges from this rent, its wings expanding almost full size instantly. It stands a moment on the surface and then rises and flies away to the shore." Heptagenia was seen emerging under laboratory conditions by Clemens. He says, "they were observed to crawl up sticks placed in the breeding jar for the purpose and transform just above the water-level."

Some species are apparently able to adapt themselves to varying conditions, as is shown by their ability either to crawl up some solid support or else arise directly from the surface of the water. This is the case in *Chirotenetes albomanicatus* as described by Miss Morgan. She writes: "They crawl up on the shore, leaving their cast skins clinging to the stones or less often they flew up directly from the mid-current." Needham's ('05) statement regarding the same species: "Transformation takes place at the surface of the water as in other species," was made some years before Miss Morgan published her observations. It is merely an example of the fact that our knowledge of habits is subject to modification and it leaves open the possibility that the case I have described may concern some species for which other descriptions have been given, perhaps a Hexagenia or a Heptagenia.

Of the various accounts concerning emergence given in the literature, a description by Miss Morgan for *Iron fragilis* (Heptageninæ) appears to resemble the instance reported to me most closely, so far as the ability to fly immediately upon emerging from the water is concerned. I do not mean to imply any identity of species. Miss Morgan says, "The nymphs popped from the surface of the water and flew unsteadily upward. * * * " She was probably not in a situation which enabled her to describe what occurred before this, but presumably some preliminary processes took place beneath the surface. Another account which bears some resemblance to the one I have given is by W. E. Howard and concerns *Polymitarcys albus*. "I have seen the subimagos emerge and arise from the surface of the water in great numbers, but always just far enough from shore so that the nymph skins were immediately swept into the current. * * * " Somewhat

similar to this is Needham's description of the emergence of *Caenis diminuta*. "It emerges from the water at nightfall leaving its nymphal skin floating on the surface, and, alighting on the first support that offers, sheds its skin again. * * * "

In neither of the last two accounts is it definitely stated whether the mayfly issued from its nymphal skin after reaching the surface of the water or whether the process began before that. In the case of *Iron fragilis* with regard to which Miss Morgan uses the phrase, "popped from the surface of the water," it would appear that the shedding of the nymphal skin must have occurred beneath the surface. The emergence I have described, is, I believe, the only case on record in which such a process has actually been observed.

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A NEW TYPE OF BRYOZOAN GIZZARD, WITH REMARKS ON THE GENUS BUSKIA.

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A certain few of the Ctenostome Bryozoa have long been known to possess a gizzard or grinding organ at the cardiac end of the stomach, though such information may be sought for in vain in nearly all text books dealing with the group.

This structure is best known in the genus *Bowerbankia* Farre, owing to the work of Hincks (1880, text figure on p. xxiii and discussion on pp. xxiv-xxvii), and especially to the excellent histological description by Calvet (1900, p. 227–230, 232–234, Pl. VI, Fig. 13 and Pl. VII, Fig. 4).

Davenport (1891, p. 63) incorrectly homologizes the gizzard with the lower end of the chilostome œsophagus. Calvet (1900, p. 233) is undoubtedly correct in stating that it is the cardiac end of the stomach which is thus modified.

The genera *Amathia* Lamouroux, *Vesicularia* Thompson and *Avenella* Dalyell also possess a gizzard similar to that of *Bowerbankia*. All of these genera belong to the family Vesiculariidæ.

In the foregoing genera the gizzard has the appearance of a rounded distension of the cardiac end of the stomach, or, to quote Calvet (p. 228), "la forme d'une sphere tronquee aux deux poles." The epithelial lining of the gizzard consists of enlarged and elongated cells which are easily visible under the ordinary low power of the microscope. The walls of these cells at their inner free ends are heavily chitinized, so that each cell thus presents a separate pointed chitinous tooth for the trituration of the food, (see Fig. 8). The bryozoan gizzard as thus described is unique in its armature.

A strong layer of circular muscles completes the grinding apparatus, which operates by rhythmic contraction and relaxation. Hincks (1880, p. xxvii) states that he has seen the food, after passing through the gizzard, driven back into it by a retrostaltic movement of the stomach and again submitted to its action.

The new type of gizzard to be described has been discovered in another family of the Ctenostomata, the Buskiidæ, of which the genus *Buskia* Alder is the only representative. Alder (1856, p. 156) failed to note the presence of a gizzard in *B. nitens* and Hincks (1880, p. 532) also failed to discover it. Later Hincks (1887, p. 127) described *B. setigera* from the Mergui Archipelago, again failing to note the presence of a gizzard. The small size of the individual in *Buskia* (in *B. armata* the length is .6 mm. and the breadth .2 mm.) and the much smaller size of the gizzard in comparison with that in the Vesiculariidæ, together with the fact that it is divided into lobes, are responsible, no doubt, for this failure to find it.

In 1912 Osburn (p. 256) re-described Verrill's *Vesicularia armata* under the name *Hippuraria armata* (Verrill). In his original description Verrill (Verrill and Smith, 1874, p. 710) had not noticed the gizzard in this species. Osburn figured and described the gizzard for the first time (p. 256, Pl. XXIX, Figs. 84a and 84b). See Figures 1 and 2.

More recently Harmer (1915, pp. 85–89) has restudied the genus *Buskia* and has found a gizzard in *B. nitens* and *B. setigera*. If his figures (Pl. 5, Figs. 10, 15 and 16), which are small and not detailed, are to be relied on, the gizzard in these species is of the same type as in the *armata* of Verrill. Harmer indicates that *armata* belongs to the genus *Buskia* and is closely related to *B. setigera*, a conclusion with which we are quite ready to agree. There is reason for considering it a distinct species, however, for *armata*, as far as observed, does not possess basal spines for the firmer attachment of the zoœcium and the zoœcial wall is not perfectly transparent as described by Hincks, but is of a yellowish horn color. *Buskia armata* should be kept separate for the present at least, especially since its distribution in the North Atlantic lies to the northward and it tends to disappear toward the tropics.

Osburn's description of the gizzard (1912, p. 256) is as follows: "a small but distinct gizzard, not completely surrounding the gut, but forming several rounded lobes, with pointed teeth projecting into the cavity." The four lobes of the gizzard, with a band of circular muscles, is shown by Osburn in Plate XXIX, Figs. 84a and 84b.

The nature of the gizzard lobes and their mode of formation have been worked out by the junior author. The grinding

structure consists of four mamillate, or low, rounded-conical structures, which are heavily chitinized, provided with pointed chitinous teeth of varying length and thickness and which are continuous with the chitinous cone. The arrangement of these cones, with their bases directed outward, gives a somewhat squared outline to the gizzard in cross-section, as shown in Pl. I, Fig. 3. The rounded surfaces, with the teeth projecting into the lumen of the digestive tract, practically close the cavity when the gizzard muscles are contracted, and the teeth are interdigitated when in this position. In operation in the living specimen, the gizzard lobes are seen to separate for some distance and then to close strongly and sharply together.

While in *Bowerbankia* and related genera each epithelial cell of the gizzard is chitinized on its grinding surface (see Fig. 8), thus making as many teeth as there are cells, in *Buskia* this is not the case. The hollow concavity of the chitinous cone is filled with elongated epithelial cells, those nearest the center being the longest. Together these cells secrete the chitinous lobe as one continuous structure, the teeth also being a part of the mass (Figures 3 to 7).

With its band of muscles, the entire gizzard in *Buskia armata* measures only about .075 mm. in diameter. Each cone measures about .0414 across the base and about .0234 in height. The teeth are quite variable in size but average about .007 mm. in height. Each cone bears about 30 teeth, though often the number is much less than this, and the teeth at the tip of the cone are larger and stronger than those farther down on the side. The layer of chitin is about .002 mm. in thickness, when fully developed, but thins out somewhat toward the base and then suddenly becomes thickened at the margin to form a ring about the base. The teeth are conical and hollow at the base and the chitin forming them is somewhat thicker than that of the cone on which they are borne. These relations are well shown in Figures 3 to 7.

Much variation is shown in both sections and total mounts in the exact form of the chitinous cones, possibly depending somewhat upon the amount of chitinization. Sometimes the lobes are almost hemispherical and seem to lack the rim around the base. As such structures appear thinner and lighter in color, it is probable that they have not reached their full devel-

opment. The teeth also vary much in form, size, number and the angle at which they project.

The difference in the structure of the gizzard affords additional evidence for the separation of the family Buskiidæ from Vesiculariidæ, the other family in which a gizzard is known to occur. That *Buskia* represents a higher specialization in the formation of a grinding organ can scarcely be doubted. There are other evidences of a more highly specialized condition in the greatly elongated and spiral arrangement of the bristles supporting the collar and in the mode of branching, (see Fig. 1). The presence of a lateral membranous area also marks this family off sharply from the Vesiculariidæ.

Buskia armata (Verrill) is the only species thus far recorded from the Atlantic coast of North America. Its known distribution is from Massachusetts Bay to Beaufort, North Carolina. On the southern New England coast it grows profusely, spreading over hydroids, algæ, etc. In this region it often rises in free branches more than an inch in height, but toward the limits of its range only the creeping adherent stage is seen.

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EXPLANATION OF PLATE.

Figures 1 and 2 are from Osburn's Bryozoa of the Woods Hole Region. Figure 8 is modified from Calvet, Bryozoaires Ectoproctes Marins. Other figures by the junior author.

Fig. 1. An individual of *B. armata* (Verrill), the zooid retracted. The gizzard is shown in partial side view (at G) and the spiral bristles of the collar (at B).

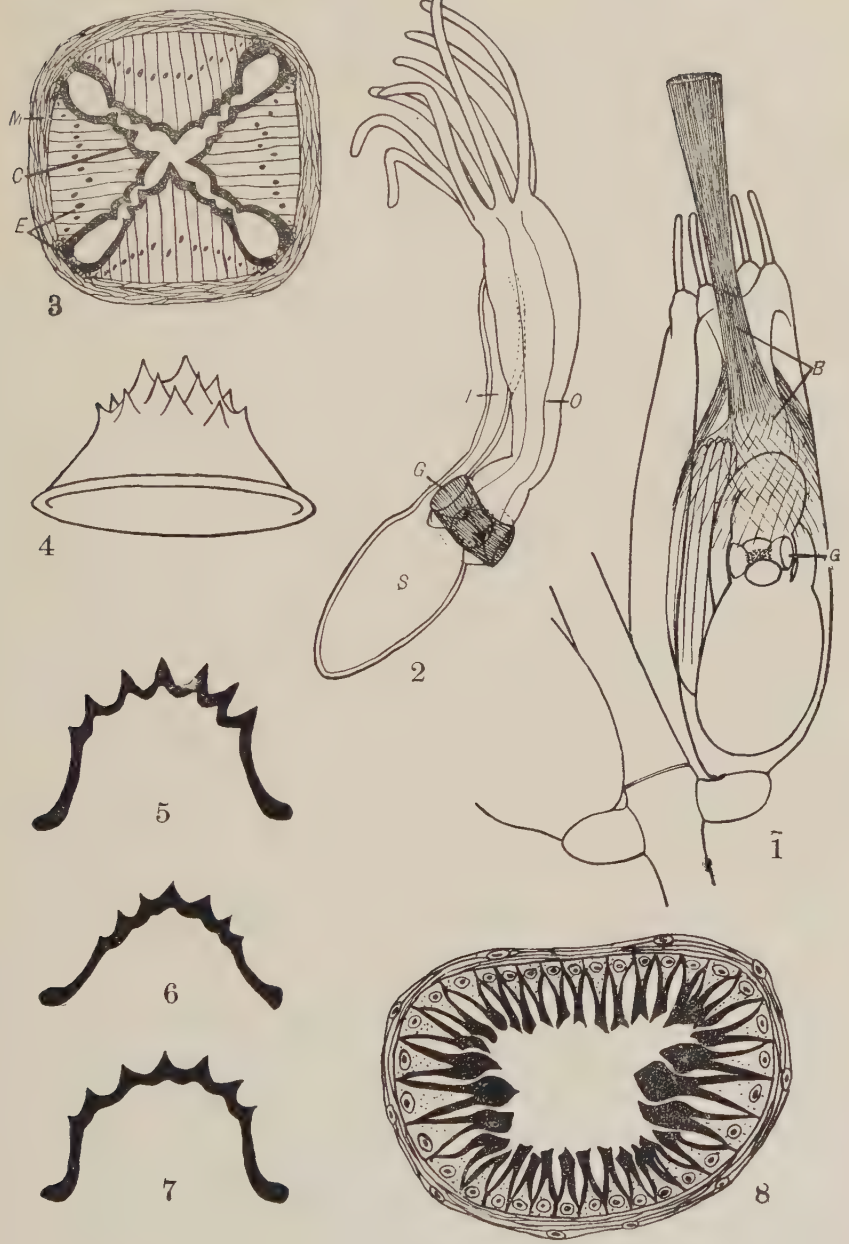
Fig. 2. Complete intestinal tract, showing the oesophagus (O), gizzard (G), stomach (S) and intestine (I).

Fig. 3. Diagrammatic cross-section of gizzard showing circular muscles (M), epithelium (E) and chitinous cone (C) with teeth.

Fig. 4. Diagrammatic side view of a cone showing the arrangement of the teeth and the thickened rim around the base.

Figs. 5, 6 and 7. Camera lucida drawings of actual cross-sections of different cones. Some of the differences in form may be due to the fact that they are not cut quite in the same direction.

Fig. 8. Cross-section of the gizzard of *Bowerbankia* for comparison. Note that here each epithelial cell bears its own chitinous tooth. The enlargement is much less in this figure than in the others.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HABITS OF THE COMMON MOLE.*

Scalopus aquaticus machrinus, (Rafinesque).

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In the United States there are five genera of moles, Scalopus, Parascalops, and Condylura appear in the eastern portion; Scapanus and Neurotrichus are found west of the Rockies. Of these genera, Scalopus is most widely distributed and consequently best known and most divided into species and sub-species. Jackson, in "A Review of the American Moles," has thirteen varieties of Scalopus listed and described along with their geographical distribution. His work on moles is notable and his analytical key gives an easy means of identifying varieties, doing away with much of the confusion arising from the same variety of mole appearing in various localities under as many as twenty different names, the genera being confused as well as the species.

The mole upon which this paper is based is *Scalopus aquaticus machrinus* (Rafinesque). The observations regarding it will deal primarily with those points to which other writers have given little or no attention, or points upon which I have found conflicting statements.

Moles are often said to be entirely insectivorous. This statement, no doubt, is based upon dentition study, for the study of the stomach contents will soon prove that moles are rather omnivorous. It is commonly known that a large percent of their food is made up of earthworms which they detect in the soil through the use of the tactile hairs and the sensitive nose. I have noticed that the motion of a wriggling worm along the side of a mole will cause the latter to turn quickly and press the worm down with the front feet and the head. The mole then waits for further activity on the part of the worm, apparently depending upon this to show just where it is. If there is no further activity the mole turns its nose about in an effort to locate the worm, presumably using the sense of

* Part of a thesis offered in partial fulfillment of the requirements for the degree of Master of Arts from Ohio State University.

smell under these conditions. The nose is usually in motion, but it is my belief that it is through a sense of touch rather than through a sense of smell that the nose is most useful in food getting when the food taken is alive and has the power of motion.

I have found their method of eating earthworms interesting. Small worms like *Helodrilus foetidus* (Savigny) and *Helodrilus caliginosus* (Savigny) are eaten entire, but larger worms like *Lumbricus terrestris* (Linnaeus) are torn to pieces with the claws. A mole may work several minutes upon a large worm, tearing it into strips and short sections, rolling it about with the front feet and the mouth, thus getting the parts of the worm almost free from the ingested earth before eating them.

Whenever I have offered captive moles any of the insects or insect larvæ commonly found in the soil, they ate them greedily. Beetle larvæ, ants, maimed flies, and small crustacea were all eaten. Large beetles such as Lachnosterna and Lucanus were also eaten, but the wing covers and hard parts of the exoskeleton were generally refused. Prof. E. L. Mosley has found that captive moles refuse wooly insect larvæ, adult Colorado potato beetles and their larvæ. Analysis of stomachs of moles show a preponderance of earth worms, a large percentage of larvæ of Lachnosterna in season, various Carabidæ, and insect larvæ of different sorts. The most noticeable insect larvæ were those of the Elateridæ, no doubt due to the fact that their tough bodies resist mastication more than the soft bodies of other insect larvæ. In the stomachs were also found insect pupæ, earthworm egg cases, grains of oats, corn and grass. One mole taken from a clover field in December had 95% of the stomach contents made up of small ants, and since the ants were all of one species, this indicates that moles are given to plundering ant hills.

Grass found in the stomach was at first thought to have been introduced accidentally until a captive mole was found to eat grass, making as high as one-fourth of a meal upon fresh lawn clippings. This led to further experiments with wild and captive moles to find out what vegetable food they might take. It was shown, to the author's satisfaction at least, that moles are guilty in some cases of eating sprouted corn and in rare instances of eating roots and tubers. Moles in captivity, when short of water, ate Irish potatoes regularly, and would

eat freely of apples, apple being taken by some moles very shortly after they had been captured. None ever ate sweet potatoes or parsnips. One ate only sparingly of carrots. The study of marks upon partially eaten Irish potatoes has led some to say that moles could not have made them, but that they were made by mice. My observations of captive moles show that marks resembling tooth marks of mice are made by moles, both by the teeth and the claws of the front feet.

Moles in captivity will eat soaked corn readily and will live for several days upon this diet alone. When this diet has been supplemented with apples and earthworms three or four times a week I have succeeded in keeping moles alive for as long as forty-one days. Soaked wheat and oats are not as readily eaten as is soaked corn. It seems that when a mole burrows unerringly along a corn row, he not only follows the line of least resistance through the soil, provided by the mark of the planter shoe, but he also eats some of the corn along with other food found. Whether the corn is eaten or not, the young plants usually die from having their root systems torn to pieces.

Moles will usually take meat when captive, eating lean beef, fish, fresh or salted pork, mice, frogs, and even small snakes. They have no trouble in disposing of live mice such as *Microtus pennsylvanicus* (Ord) this fact making the theory that potato tubers are eaten by mice that follow along the runways of moles very untenable. In eating furry animals the mole discards most of the hair and skin, also some of the larger bones. The hind feet and strips of skin are all that are usually left after a meal upon a meadow mouse.

The mole does not ordinarily drink. I observed only one captive mole drink, taking water by lapping. In dry summer months moles may be found far from water and in such situation must depend upon the water found in their food. It would be of interest to observe moles in dry weather when earth worms are scarce or excessively deep, to see if it is then that depredations in potato patches occur. Observations upon captive specimens indicate that plant roots and tubers are eaten chiefly to satisfy thirst.

Curiously enough, no reference is made by most authors to the swimming habits of moles. Some state that the mole can

undoubtedly swim, and one author has given the mole great powers of swimming, due to powerful strokes of the great front feet. *Scalopus aquaticus machrinus* (Rafinesque.) does swim well, but the front feet play no part in propelling the animal, they are used only in turning or in righting when not on an even keel. The front feet are held together under the chin where they cut the water like the prow of a tiny motor boat, the propeller in this strange craft being the webbed hind feet which alternate with each other in their movements. The flexible nose is held curved upwards, raising the nostrils well above the water. I have used a stop-watch upon swimming moles and find that the swimming rate averages about a foot per second. I have found the maximum speed in running to be only a little more than double the swimming rate, averaging 26.7 inches per second in the specimens tested. Both of these speeds are low, the small hind feet being poorly adapted for swimming and the large front legs so wonderfully adapted to a strong side thrust in digging are poorly adapted to running.

Moles usually bear a few external parasites, such as fleas and mites, and numerous internal parasites. Nematode worms are not uncommon in the stomach. The most common internal parasite is *Moniliformis moniliformis* (Travassos). The intestines are sometimes so clogged with these parasites that one wonders how food is able to pass along the tract. Moles containing as many as three dozen of these worms give no evidence of the fact in any way unless it be in their ravenous appetites. They must have no difficulty in supplying both themselves and their parasites with food, for even the most heavily infested moles that I observed were in good condition and seemed to have as much fatty tissue as moles not infested. Of twenty moles taken in August, 1917, the average for stomach worms was 1.2 and for intestinal worms 16.4 per animal. The intestinal worms of one animal numbered 23, their average thickness 1.4 mm. and their total length 333.5 cm. The length of the intestine of the mole was 115 cm., making the length of the enclosed parasites nearly three times the length of the intestine that held them.

The genus *Moniliformis* is placed in the subfamily *Gigantorhynchinæ* (Travassos, 1915) this being a subfamily of the *Gigantorhynchidæ* (Hamann, 1892). The members of this genus are parasites in the intestines of rodents. As far as I

know the mole has never been included in the list of hosts of this genus of Echinorynchs. If this be true it is not surprising, for I find that moles of one collecting ground may be heavily infested with the parasites, while moles a few miles away may be entirely free from them.

On account of their tunneling in lawns, flower gardens, truck patches, golf links and such places, the mole is commonly regarded as a pest. From the standpoint of his food, he is to be considered beneficial, but when a mole uproots hill after hill of melons to get the larvæ of the striped cucumber beetle projecting from the roots of the vines, the cure is decidedly worse than the disease. Once the mole finds a good feeding ground he can not be easily driven away, and if he is doing any real damage it will be found advisable to destroy the animal in some way rather than to attempt to make him seek other feeding grounds.

Experiments made by placing salt, sulphur, pepper and other irritating substances in mole runs in an attempt to drive them out of lawns and golf links have proven failures, the animal simply building another set of tunnels in another part of the lawn or golf course. One often hears that castor bean plants about a garden will keep moles away, but the writer has seen moles burrow directly under castor bean plants. Dogs can be trained to catch moles, but they will not eat them, presumably on account of their bad odor. Cats also catch moles, usually at night, they also refusing to eat the captured animal. Poisoning is one of the artificial means that may be used in reducing the number of moles, the most convenient method consisting of soaking corn, then placing strychnine or arsenic in the heart of the grain by pricking it in with a tooth-pick or other blunt instrument. The poisoned bait should be placed in the mole runways, one grain of this being sufficient to kill a mole. Care should be taken to select no poison with a decided odor, as this will lessen the efficiency of the method. I have found arsenic the most satisfactory poison to use.

The most common means of destruction, also the most efficient, is the use of traps. Traps of the nature of pitfalls have proven useless in the hands of the author, yet if they are carefully set they occasionally make a catch. Moles are often found drowned in wells walled up with boulders, but in this case it is probably thirst that causes the mole to lose his life in

this manner. Of the various spring traps set in runways, one is of equal value with another if properly set, but on account of the use to which the skins may be put, the harpoon type of trap is the least desirable.

Scalopus aquaticus machrinus (Rafinesque.) will likely continue to be an animal small in numbers among us on account of its breeding habits, for it breeds only in early spring of each year and the number at birth is small, averaging four or five. On account of its food habits and its depredations in lawns and cultivated fields, it will always be of economic value, and of special scientific interest on account of its subterranean habits and high degree of specialization.

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A CASE OF UNHINDERED GROWTH OF THE INCISOR TEETH OF THE WOODCHUCK.

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Late in the fall of 1921, long after the normal woodchucks had gone into retirement for the winter the groundhog whose head is shown herewith was caught near Oxford in a trap set for skunks. The trapper killed the woodchuck with a club, breaking two of the teeth in the process, one of which he picked up. The pelt being valueless he cut off the peculiar looking head and threw the body away making the observation that the animal was much undersized and excessively thin.

The head was brought in, mounted by a local taxidermist, and put upon exhibition in an office window. I take this opportunity to thank the exhibitor, Mr. Chas. Wright, for permission to photograph the mount.

There is no evidence as to what happened to deform the animals, but the results are clear. In some way the incisor teeth of the woodchuck's lower jaw became deflected to the animal's left side and the incisors of the upper jaw turned enough to the right so that the two sets passed each other and no longer could be kept worn down by gnawing.

The left lower incisor grew in a regular curve up to the eye, ploughed through the eye and blinded it. It can be seen that the direction of growth was changed into a section of a larger circle as the end of the tooth slid backward along the frontal bone. The continuous curving growth of the tooth was not to be resisted by bone, however, and so the point of the tooth perforated the skull a short distance behind the eye socket and is said by the preparator to have penetrated the brain also.

This perforation of the skull and brain must have been some time before the animal's death, for the last visible part of the tooth is sheathed with a connective tissue envelop probably continuous with the periosteum of the skull through which the tooth passed. How far into the brain the tooth penetrated can never be determined. The whole socket of the eye was a suppurating mass when the animal was killed.

The right lower incisor was crowded between the left lower incisor and the bones of the left side of the face. It shows the effect of pressure and also that it was rubbed between its mate and the skin of the face. The hair on the face is worn very close along the line of this tooth also. Unfortunately since it was broken across when the animal was killed, no more accurate information can be had as to its position. The photograph shows it ending freely over the part of the left lower tooth which disappears into the head.

The stump of the right upper incisor is shown on the animal's right. The tooth is curving sharply and if the part broken off could be found it might show that the point was nearly as high as those of the teeth on the lower jaw.

d. i. dx.—Right upper incisor (broken off).
d. i. s.—Left upper incisor which passes down the animal's throat.
e. s.—Left eye socket through which the lower incisor plowed.
v. i. dx.—Right lower incisor (broken off but placed about as it must have been in life).
v. i. s.—Left lower incisor penetrating the skull and brain.

The left upper incisor turns directly down and back into the mouth and, according to the man who mounted the head, extended down the throat for more than an inch.

This case is a fine example of the way rodent chisel teeth with persistent pulps (or with continuous growing germs) act when for any reason the wearing of the teeth is hindered. The fate that follows is inexorable and starvation is its logical end.

How did the animal get any nourishment at all? The bodies of the upper and lower incisors firmly fixed side by side seem to

make entrance of food into the mouth from the front absolutely impossible. There is, however, a small section of the mouth opening to the left side just behind the origins of the lower teeth which looks as though it could have been used. The hair around this corner of the mouth looks rubbed and worn thin. Possibly by turning the head to one side and by manipulating with the tongue as effectively as it could act under the permanent tongue depressor (the left upper incisor) some leaves and other small fractions of plant tissue could be forced far enough into the mouth to be caught and ground up by the back teeth.

Whatever explanation one makes concerning the method of feeding, the animal certainly obtained enough food to keep alive, for it was killed by the trapper. And from the date of capture, nearly a month after the normal woodchucks had disappeared, we can be just as sure that the creature had been unable to hibernate because incapable of accumulating fat.

There is no means of learning the age of the animal, but since these rodent teeth grow rapidly it was probably a young one and these tusk-like teeth the unworn accumulation of one season's growth. It seems impossible to imagine a half blind, deformed and infected animal ever having been able to store fat enough to live over even one hibernation period.